INCREASING THE EFFICIENCY ENERGY FOR GROUPS OF PUMPS IN CASCADE WITH PERFORMANCE AUTOMATION – EXPERIMENTAL RESEARCHES –

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This paper presents results of experimental research conducted on a group of three pumps working in cascade, with the intelligent automation - AQUAMOD

The electronic module of automation surveys the hydraulic and energetic performances, by controlling the working point position, in order to reduce the specific consumption of energy and water.

The paper presents an automation in original conception, patented, making also data acquisition and their transmission. The paper includes graphical plotting of operating characteristic curves, with frequency modulation at the entrance / exit of the pump system according to flow needs.

From the analysis of pumps and cascade group could conclude that by tracking the operating point with optimal efficiency, the energy performance is maximum, comparable with the best performance of each pump working separately.

Applied automation solution reduces energy consumption specific to the users by 20-25%, average for low power pumps and about 30% for high power pumps, and compared with known solutions in cascade groups, energy saving is 3-5% .

Keywords: group of pumps, automatic control, efficiency energy

1. Introduction

In the mechanical engineering field pumps have an important position, reason to make their work efficient, to increase the hydraulic performances and to reduce the energy consumption, simultaneous with there automate working.

In this paper we present experimental researches with an original automation solution for a group of pumps working in cascade. The electronic module surveys the pumps parameters, command, control and adjust the working parameters. The AQUAMOD automation solution integrates a special communication with frequency converter, serial on MODbus and analogical, represents the object of a patent.

AQUAMOD automation module improves the functions of pumps group working in cascade. Operating parameters of the module, adjust to the needs of the SP consumption, are input to the programmable controller and software,

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control and monitoring. Continuous monitoring of plant parameters is important to save energy and increase life of equipment. The module contains innovative elements, automation functions and reduces the gauge of the panel command and control [1], [2]. The dedicated software was included in prototype of group.

Innovative elements AQUAMOD refers to the communication with the frequency converter, made by the serial MODBus, and analogue communication with voltage 0-10V, which can explore the entire range of frequencies generated by the converter. In this way is enough to prescribe the output frequency converter for the parameters adjustment.

We made experimental researches on a group of three pumps located in the laboratory of PVSC in Hydraulic Department. By analysing the efficiency in working with variable speed results that the Aquamod automation, permanent monitoring the parameters of pumps followed in selected pumps the optimal / nominal point of work, in anyone speed. The aim to reduce the energy consumption from the users has been achieved, reducing more than 25% comparing with conventional solutions, consisting in one pump without automation.

2. Automation solution in working pumps – new elements

This paper presents a practical solution for pumps automation working, in order to reduce the specific consumption of energy and water. Our dedicated electronic module AQUAMOD surveys the hydraulic and energetic parameters by a programmable module [1], [2]. The main functions of this module consist in an automatic control of pumps, by a frequency converter to put on the main pump and also to control the auxiliary pumps – for group in cascade, by rotating the pumps which work at variable speed, for their uniformed wearing.

The automation was made for a group with three identically pumps, having 3-7.5 bar head and 2-30 m^3/h flow. The design parameters for a pump (vertical multi-stage with 8 impellers) at nominal speed are: Q =5 m^3/h, H = 7 m */stage*, n = 2900 rot/min.

This specialized module visualizes the energetic and functional characteristics, avoid the cavitations phenomenon in pumps and also protect the electric drive to overload. The electronic module surveys the pumps parameters, command, control and adjust the working parameters. The adjustment can be made in real time in site, also from distance, depending of the rate flow necessary in installation.

Specialised electronic automation consist in three modules [1], [2], [3]:

a) the main module with micro controller, for the logical operation of the assembly; on the control panel, with IP65 protection, there is a screen consisting in 4 rows with 20 characters and a keyboard for setting the parameters; this module has an output communication with the others two;

b) the second module for the electric parameters (current, voltage, power factor);

c) the third module for data acquisition and their transmission at distance by cable or by radio waves, also by telecontrol of the pumping group.

A pumping group with this automation module provides: the correct selection of the hydraulic components with high efficiency, reduced the specific consumption of energy by variable speed; speed adjustment according of the water consumption keeping constant the pressure in the system; good reliability by starting and stopping the pumps in cascade without mechanical or electrical shocks; protection of the pumps against dry operation and protection of electric drive against overloads; protection of the piping network against water hammer and overloads.

AQUAMOD innovate the communication elements serial by protocol MODBus and analogical with voltage 0-10V, so the advantages are:

- it extends types of frequency converters used, cheapest, without specialised macro for diverse applications, resulting a cheapest automation solution with same functions;
- it reduces the energetic consumptions, as consequence as variable speed and working control in the nominal point for long time;
- the reliability increase by put on / cut off in cascade, without mechanical or electrical shocks, protecting the pumps at water absence, protecting the electric drives at shorten and overload.

This specific automation solution AQUAMOD is illustrated in figure 1 and was patented [3].

AQUAMOD is an electronic module for automatic control and survey of a group of maximum 5 pumps. It assure the pumps command, the frequency converter, determination of electrical and technical parameters and theirs display, the events and damages storage in the communication with other external devices.

Fig. 1. Automation control

AQUAMOD work can be autonomous or with remote control.

Mounted on the automation panel door, equipped with LCD, keyboard and LED signalling, AQUAMOD assure direct access of the operator to view the measured parameters quality, the system states and damages. Parameters programming (e.g. pressure at the last user) can be made locally with password.

The automation functions realise:

a) Order of the pumps depending on the available status (damage), signals of technological parameters (sensors, transducers), the working time for each pump.

b) Measurement of the electrical and technological parameters:

- three phase voltages, three phase current at the entrance switchboard or on each pump in manual mode;
- active power and total power for the pumping group or for each pump in manual mode;
- technological parameters taken from transducers and sensors (pressure, flow, level, temperature);
- electrical parameters from transducers (current loop, voltage excitation)

c) Damages and alarms - detect storages and display a lot of type of damage. Faults are stored with time and order of appearance, like incorrect phase sequence, no voltage, the voltage unbalance between phases, over-voltage, under-voltage , transducers damages 4-20 mA;

- frequency converter failure with his reported code, temperature rise inside the panel.

d) Communication - In order to communicate with the frequency converter integrated in a survey system with remote control, AQUAMOD is equipped with serial RS485 interface that use MODBUS protocol. To communication with other functional modules (network monitor, module BMS, s.o.) I2C serial output is provided with one's power supply. On board there is a connector for relay extension to control pumps 4 and 5.

Electronic module menus are: configuration, menu pressure-flow, PID setting, thermostat, time setting and network monitor.

3. Experimental researches – hydraulic and energetic performances

This paper presents the experimental researches on a group of 3 pumps working in cascade with this new automation panel.

During the experimental researches was surveyed and plotted the characteristic curves for a pump at nominal speed, then at variable speed and working in cascade for 2 and 3 pumps:

$H = f(Q)$, $P = f(Q)$, $\eta = f(Q)$ for nominal speed,

$H = f(Q)$, $P = f(Q)$, $\eta = f(Q)$ for variable speed,

$H = f(Q)$, for 2 and 3 pumps in cascade.

Main parameters in pumps working are: the head H [m], the flow Q [m^3/h], electric power consumed from the system P[kW] and the equipment efficiency η [%], [4], [5], [6], [7].

From the inlet and outlet pressure transducer indication can obtain the total head, displayed on the panel screen.

For flow measurement we use an electromagnetic flow meter FLOMAG 5100 W DN 50 / 2" with sensor for automation. At different valve opening, the instantaneous flow is displayed on the panel screen.

Also electric power consumption is displayed. On repeat the experiments for many valve openings, from fully closed to fully open, by simulating different flow rate demanded from consumers, to trace the characteristic curves at constant speed, at variable speed decreasing the flow and at flow rising over one pump, in cascade working with 2 or 3 pumps – task realised by the automation panel .

To determinate the pumps efficiency, is compared the hydraulic power with the pump power drive $P_{a.}$

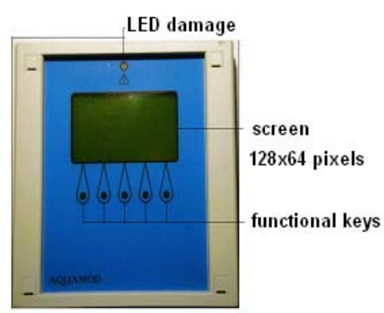
Optimal working parameters for a pump, conform with catalogue curves [9], [10] are : Q = 5 m^3/h, H = 58 m, P = 0.16 x 8 = 1.28 kW (an electric drive power = 1.5 kW), P group=4.5 kW, $NPSH$ = 0.8 m and optimal efficiency is η_p = 61%.

Automation receive information from two pressure sensors / transducers, 2 bar for the suction and 10 bar for the discharge, a level sensor, temperature sensors / thermal relays on the pump's drives.

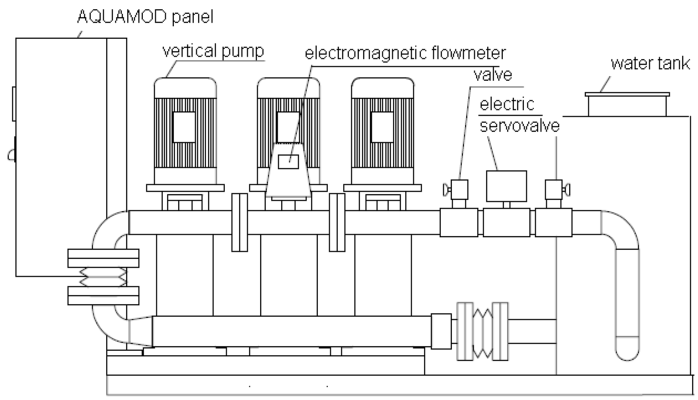
The electromagnetic flow meter FLOMAG 5100 W DN 50 / 2" with communication sensor has chosen for lows between 2 and 60 m^3/h.

In figure 2 is presented the photo of group of pumps (2a), the scheme of the experimental installation (2b) and a detail on the screen of the panel (2c).

2a.



2b.



2c.

Fig.2. The group of pumps with automation –2a. photo, 2b.screen' s detail
2c. scheme of the experimental installation

Table 1

Q [cm/h]	H [m]	n [rpm]	P [kW]	η [%]
50Hz				
1	77.0	2930	0.800	26.23
2	73.1	2932	0,904	44.07
3	69.0	2932	1.040	54.26
4	62.5	2935	1.184	57.53
5	56.7	2934	1.264	61.11
6	47.6	2932	1.320	58.95
7	39.5	2933	1.352	55.73
8	30.0	2932	1.352	48.37
45Hz				
0.9	62.37	2639	0.583	26.04
1.8	59.21	2640	0.659	43.76
2.7	55.91	2641	0.758	53.88
3.6	50.63	2643	0.863	57.13
4.5	45.93	2642	0.921	60.69
5.4	38.56	2641	0.962	58.54
6.3	32.00	2640	0.986	55.34
7.2	24.30	2640	0.986	48.03
40Hz				
0.8	49.28	2343	0.410	25.96
1.6	46.78	2344	0.463	43.63
2.4	44.18	2345	0.532	53.71
3.2	40.00	2347	0.606	56.96
4	36.29	2347	0.647	60.50

4.8	30.46	2344	0.676	58.37
5.6	25.28	2344	0,692	55.17
6.4	19.20	2343	0.692	47.89
35Hz				
0.7	37.73	2052	0.274	25.91
1.4	35.82	2053	0.310	43.54
2.1	33.82	2053	0.357	53.61
2.8	30.63	2053	0.406	56.84
3.5	27.78	2054	0.434	60.38
4.2	23.32	2053	0.453	58.25
4.9	19.36	2053	0.464	55.06
5.6	14.70	2053	0.464	47.79
30Hz				
0.6	27.72	1759	0.173	25.89
1.2	26.32	1760	0.195	43.49
1.8	24.85	1760	0.225	53.55
2.4	22.50	1761	0.256	56.79
3	20.41	1761	0.273	60.32
3.6	17.14	1761	0.285	58.19
4.2	14,22	1760	0.292	55.00
4.8	10.80	1760	0.292	47.74

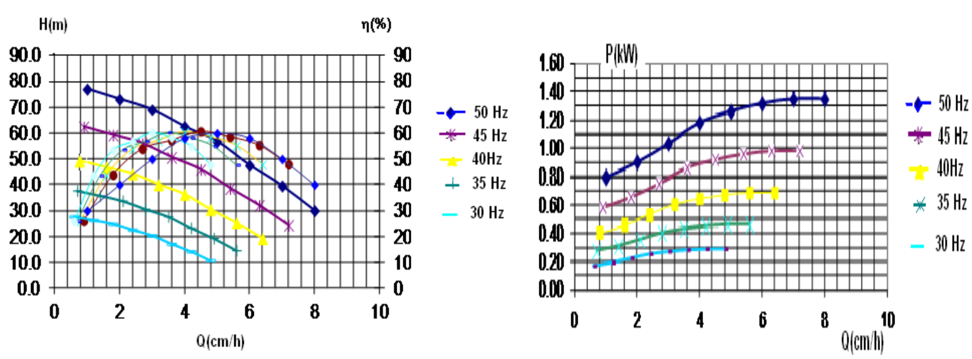


Fig. 3 Characteristic curves with frequency converter

Using AQUAMOD with frequency converter was obtained a decreased power consumption P=1.26 kW and an increasing efficiency at 61.12% for nominal speed, but at the reducing speed 20 Hz, the efficiency has varied with 1.5% compared with that at the nominal speed, that because the automation software surveyed permanently the optimal working point, with maximum efficiency. Comparing with known pumps with automation [8], [9] was realised an energy consumption reduced with 5 % working at nominal speed proximity and reduced with 3 % working at minimal speed. The automation software has surveyed permanently the optimal point of the characteristic curves. In figure 4 is illustrated the characteristic for 3 pumps in cascade. AQUAMOD module supports maximum 5 pumps.

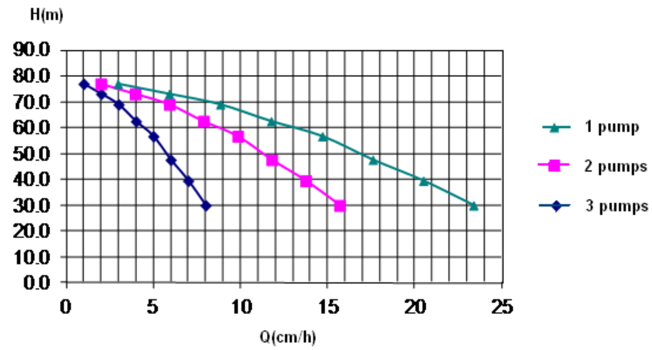


Fig. 4. Characteristic curves for 3 pumps in cascade

4. Energy saving

On the same group of three pumps were performed experiments with classical automation with frequency converter and were found differences in displayed parameters. For example the power displayed in the optimal working point was $P_v = 1.327$ kW at frequency of 50 Hz and $P_v = 0.282$ kW for 20 Hz frequency.

Higher powers consumed is due to the absence of those functions of automation which, based on feedback from the converter, adjusts the operating parameters of the group. Thus, comparing the old values with the values from Table 1 can be established that:

$$\varepsilon = \frac{P_v - P_n}{P_n} = .\frac{1.327 - 1.264}{1.264} = 0.0498; \quad \varepsilon(\%) = 0.0498 * 100 = 4.9\%$$

for powers displayed at 50 Hz frequency.

Thus, reducing power consumption and consequently the energy was almost 5%.

$$\varepsilon = \frac{P_v - P_n}{P_n} = .\frac{0.282 - 0.273}{0.273} = 0.0329; \quad \varepsilon(\%) = 0.0329 * 100 = 3.29\%$$

for powers displayed at 20 Hz frequency.

Thus, in this case is energy saving 3.3%.

Was noted P_v – the old value of power and P_n – the new value or power displayed.

Pumping station residential or industrial using pumping group with automation panel AQUAMOD, decrease the average specific power consumption with 25 % for small and medium pumps, and with 30% for large pumps, comparing with classical solutions [8], [9].

This automation module increase the lifetime of the pumps and reduce the operating costs.

With a group of 4 pumps with electric drives of 5.5 kW – like that used in Central library of University Polytechnic a of Bucharest, annual energy economy is estimated at 2000 Euro / year, meaning that the investment in a group with automation AQUAMOD can be recovered in 3-4 years from energy savings, as illustrated in figure 5.

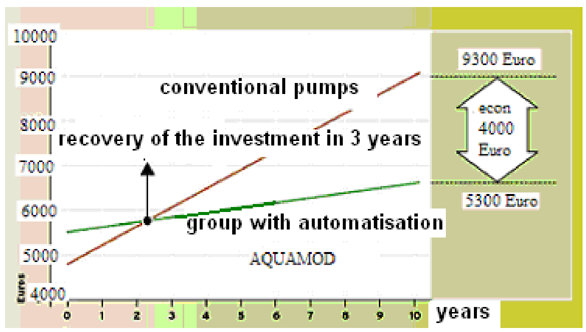


Fig. 5. The investment recovery

5. Conclusions

The automation working of pumps proposed by AQUAMOD is a performed solution consisting in an automatic control of pumps, by a frequency converter to put on the main pump and also to control the auxiliary pumps – for group in cascade. The main aims of automation of pumps were to reduce their energetic and water consumption.

The automation electronic module surveys the hydraulic and energetic performances, controlling the working point position, at maximum efficiency. So, the energetic performances are maximal, compared with the best efficiency of each pump working separately.

The automation solution applied in SP reduce the specific average energy consumptions at the users with 20-25% for small pumps and about 30% for big pumps, and comparing to the classical solutions for pumps working in cascade, the energy economy is between 3-5%.

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